THE BALLOON PROJECT AND WHAT WE HOPE TO ACCOMPLISH.[1]

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In times past, the manned free-balloon has been extensively used for the collection of meteorological information. One needs but to look at the ponderous *Wissenschaftliche Luftfahrten* of Assmann and Berson to appreciate the elaborateness with which some of these experiments were carried out. But such efforts were directed largely toward the measurement in the vertical of meteorological elements such as temperature and humidity, and these can now be made regularly and frequently by means of kites and sounding balloons under much more satisfactory conditions of instrument exposure, and certainly at much smaller expense. Free ballooning in the interest of science, therefore, has not been extensively practiced in recent years; and the contribution of the free balloon to the advancement of meteorological science since the early days of aerology has been scant indeed, in spite of the perennial claims of those who would thus justify the excellent sport of balloon racing—a sport which really needs no such justification.

There are, however, certain meteorological problems which can best be investigated by means of the manned free balloon, and it was with such problems in mind that the Chief of the Weather Bureau approached the Chief of the Army Air Service with a proposal for a cooperative project to be carried out from an Air Service post. The response of the Air Service was immediate and favorable, and, at the time of writing, arrangements have been practically completed.

History.—A word concerning the history of the experiment may be in order. While stationed at Fort Omaha, Nebr., as Signal Corps meteorologist during a few months following the armistice, the writer had the opportunity to engage in free-balloon flights which were then being made chiefly for training purposes. Upon consulting the Central Office of the Weather Bureau as to meteorological observations that might be made during such flights, information was received that flights at constant elevations of as great duration as possible might be the best contribution. Through the kind cooperation of the commanding officer at Fort Omaha and the Air Service officials in Washington, plans were consummated for the flight of two balloons, each carrying two officers, one balloon to maintain an elevation of 10,000 feet and the other 5,000 feet for as long a time as possible. The full moon, riding in the clear sky of the night of April 16, 1919, saw the getaway of these two balloons, and the bright afternoon sun of April 17 saw the lower one land at Cabot, Ark., and the higher land at Arcola, Miss.[2]

Circumstances were not auspicious for the carrying out of further long flights of this character at that time, but, with his discharge from the Army and his assumption of duties in the Weather Bureau at Washington, the writer has cherished with undiminished enthusiasm the desire to make a series of such flights, carefully planned to take advantage of selected weather types and to utilize to the fullest extent synchronous observations at the surface and in the free air. The time seems now to be propitious for this effort.

Scott Field, Belleville, Ill., has been designated as the post from which the flights will be made, and a qualified pilot has been assigned by the commanding officer to the duty of collaborating with the Weather Bureau's representative in carrying on the work. The flights, of which it is hoped to make approximately 15, will start about April 1.

Free-air trajectories.—Meteorologists are familiar with the interesting trajectories of surface air deduced by Shaw and Lempfert in their studies of wind movement in relation to barometric situations in and about the British Isles.[3] These trajectories clearly showed that our conception of the circulation about centers of low and high pressure, based solely upon the instantaneous stream lines and synchronous wind arrows of the daily weather map, may be quite erroneous if the pressure systems are not stationary. Much depends, therefore, upon the rate of translational motion of the isobaric systems relative to the rate of motion of the individual air particle which forms a part of that system. It was shown by Shaw and Lempfert that some trajectories of surface air are loops, some are sweeping curves, and some nearly straight lines, while many converge and end abruptly, apparently indicating ascent of air. These interesting deductions were made from hourly pressure maps and observed wind directions in combination with the judicious use of gradient wind relations when observations were not available.

But those trajectories refer only to surface air. Nothing has been done with air trajectories at higher levels, probably because there were available neither sufficiently numerous observations nor synoptic free-air pressure maps. This series of free-balloon flights will be given over primarily to the determination of trajectories of air at levels above the earth's surface. A balloon maintaining a constant elevation will describe a path over the earth's surface which will constitute the best possible approximation to the trajectory of an air particle at that level. While it is clearly recognized that difficulties will be encountered in maintaining a constant elevation under all conditions, it is believed that results of a high order of accuracy may be obtained.

In connection with previous work in the reduction of free-air barometric pressures, a number of Weather Bureau stations have been called upon to assist.[4] In a like manner, these stations will be asked to carry on daily pressure reductions to free-air levels throughout the period of these flights. The free-air maps thus made available will make possible comparisons between observed and theoretical trajectories, and, perhaps, permit us to know what degree of confidence we may legitimately have in conclusions regarding free-air movements based solely upon the maps.

Recent studies in the mechanism of cyclones and anticyclones, such as the kinematical investigations of Kobayasi[5] and Ryd,[6] and the dynamical studies of Bjerknes,[7] have served to emphasize the great and immediate necessity for observations as to the nature of air trajectories at various levels in cyclones and anticyclones.

[1] Presented before the Weather Bureau Staff at its meeting of Feb. 20, 1924.

[2] Meisinger, C. Le Roy: The constant-elevation free-balloon flights from Fort Omaha. MO. WEATHER REV., August, 1919, 47: 535-538.

[3] Shaw and Lempfert: The life history of surface air currents. *M. O. No. 174*, London, 1906.

[4] Cf. Meisinger, C. LeRoy: Concerning the accuracy of free-air pressure maps. MO. WEATHER REV., April, 1923, 51: 190-199.

[5] Kobayasi, T.: On the mechanism of cyclones and anticyclones. *Quarterly Journal of the Royal Meteorological Society*, July, 1923, pp. 177-189.

[6] Ryd, V. H.: Travelling cyclones. *Publikationer fra det Danske Meteorologiske Institut, Med. Nr. 5*, Copenhagen, 1923.

[7] Bjerknes, V.: On the dynamics of the circular vortex with applications to the atmosphere and atmospheric vortex and wave motions. *Geofysiske Publikationer*, Vol. II, No. 4. Christiania, 1921.

Trajectory determinations.—It is apparent that the success of these observations is largely dependent upon the accuracy with which the momentary position of the balloon can be determined. This may be accomplished in any or all of three ways. First, without clouds below the balloon, it is a relatively easy matter to ascertain one's position by comparison of topography with reliable maps. Even on dark nights, cities and towns, streams and railroads, and other landmarks are quite easily distinguishable. When clouds obscure the land below but heavenly bodies are visible above, the position of the craft can be quite accurately determined by the usual methods of navigation, using an aircraft sextant with bubble horizon.[8] Such sextant observations should be quite satisfactory when made from a balloon, since this type of craft is relatively free from accelerations and decelerations to which an airplane is constantly subjected and which have so marked an effect upon the bubble horizon, and, consequently, upon the accuracy of the position determination. Finally, under any conditions of uncertainty as to location, bright-colored cards, conspicuous when lying on the ground, may be dropped. These may be printed in bold-faced type, addressed and franked, and the finder is asked to tell simply his name and the place and time of finding the card. He is requested to drop the card in the nearest mail box. In the case of the flight from Omaha mentioned earlier, about one-third of the cards dropped were returned. They were slightly weighted with small pieces of lead so as to increase the rate of fall and, consequently, reduce the amount of drift. The wisdom of this was shown in the good agreement between the known path of the balloon and the points where the cards were found, even when the cards were dropped from 10,000 feet.

Flights at other than constant elevations.—Not all the flights will be made at constant elevation. Some will be made with a view to taking advantage of over and under running winds. An attempt will be made to map out in advance as nearly as possible the desired barometric conditions in which the flights should be made, and then, as such conditions appear, take advantage of them so far as we may be able. Much will depend, therefore, upon the liaison that must be maintained by telegraphy and radio telephony between the forecaster at Washington and the balloonists.

Relations between forecasters and balloonists.—This liaison, as at present contemplated, will work in somewhat the following manner: The balloonists, having reported to the Washington forecaster their return to the field from the previous flight, and having indicated their availability for the next flight after a certain time (this being dependent upon availability of balloon and equipment and to some degree upon physical fatigue), the forecaster observes upon the weather map the approach of conditions suitable for carrying out a certain phase of the experiment and wires this advice to the balloonists who prepare promptly to act upon it. Just before taking off, a telegram is dispatched to Washington indicating the time of take-off and certain radio broadcasting stations which will be listened to at prescribed times for the reception of weather bulletins and further meteorological advice gleaned by the forecaster from the latest weather map which shall have been constructed since the take-off. A brief description of the map will make possible the construction in the balloon of an approximate copy for the study of the balloonists. If the balloon is yet in the air 12 hours after the first bulletin certain other broadcasting stations will be listened to for additional reports. Immediately upon landing, the Washington office will be notified of the fact, and the contemplated time of availability for the next flight. This is the cycle of anticipated communications between forecasters and balloonists.

Collection of dust samples.—There are several kinds of observations that can be made during the flights. One is upon the dustiness of the atmosphere as determined by the Owens' Dust Counter.[9] The record is obtained by drawing a known volume of saturated air through a narrow slit by means of an air pump. The condensation thus produced upon dust particles causes them to adhere to a microscope cover glass firmly placed just behind the slit. The water evaporates shortly after the glass is removed from the instrument and a line of dust is left behind. Dust counts are made with a microscope after the cover glass has been mounted in the usual manner upon a slide.

Measurements of sky brightness.—Photometric observations by means of the Holophane lightmeter[10] are contemplated. This instrument is of light weight, is compact, and is, therefore, well suited to use in aircraft. The sky is directly observed through a small elliptical diaphragm and its brightness is matched by a standard electric lamp. The lamp, which illuminates a larger concentric ellipse and which may be moved forward or backward by a tangent screw, operates at a specified voltage by means of an attached rheostat. The scale reads directly in foot candles and these units may readily be converted into millilamberts, units of brightness. Such brightness measurements are contemplated for specific points in the unclouded, or uniformly clouded, sky, at various elevations of the balloon.

Size of cloud droplets.—It was anticipated, also, that some measurements might be made upon the angular diameter of coronæ formed about a small, but bright, electric light when passing through clouds. This is a diffraction effect, and if the angular diameter were measurable, it would be related in a known manner to the diameter of the intervening cloud droplets. The success of such measurements seems to depend upon the uniformity of size of the droplets and the brightness of the light, and it is also essential that the light impinge upon the particles in a roughly parallel manner. A thin cloud of lycopodium powder blown into the air between the observer and the light near the observer yielded brilliant coronæ to the fourth order, but, in viewing the light through a thin cloud of steam the corona of the first order was observed but faintly, and much too faintly for accurate measurement. It is to be inferred either that the light was not sufficiently bright (although a lamp of small filament operating at considerable overvoltage was used), or the steam particles were of nonuniform size. In any case, the lack of complete success in preliminary experiments makes it advisable to hold this effort in reserve and continue experiments actually in the clouds.

Other instrumental equipment.—As a part of the instrumental equipment an Assmann aspiration psychrometer will be carried as well as the barograph element of a kite meteorograph. The object will be to keep an accurate

[8] Eaton, H. N.: Aerial navigation (Pt. II), *U. S. Air Service*, October, 1923, pp. 39–44. *Also* abstract entitled *Air navigation*, by J. P. Ault, *Journal of the Washington Academy of Sciences*, Aug. 19, 1923, pp. 334–335.
Hunt, F. L.: Aeronautic instruments. *Technologic Paper of the Bureau of Standards, No. 237.* Pp. 493–497.

[9] A description, together with a photograph, of this instrument and an account of its use in collecting dust samples during airplane flights will appear in a later number of the REVIEW.

[10] *Transactions of the Illuminating Engineering Society.* Vol. XV, No. 8, 1920.

record of the temperature as indicated by a ventilated thermometer and of the pressure as recorded by a sensitive and carefully calibrated barograph. These two elements, in combination with the surface temperature and pressure will enable one to compute the altitude of the balloon and thus check its altitude against that indicated by the altimeter. A camera will probably be carried also, and photographs of clouds obtained whenever opportunity affords.

Conclusion.—This short discussion indicates briefly what it is hoped to accomplish during the balloon flights. While it is believed that this program can be quite closely adhered to, it should not be forgotten that in undertakings of this character unanticipated difficulties may arise to interfere more or less with the orderly prosecution of the work. The final report of the flights will indicate the degree of success enjoyed in this attempt at scientific ballooning.

A METHOD FOR LOCATING THE DECIMAL POINT IN SLIDE-RULE COMPUTATION.

551.501

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The slide rule has come to be, in rapid computations in the field and elsewhere, what logarithms are in more refined computations. In several branches of the work of the United States Weather Bureau the slide rule is used extensively, particularly in the Aerological Division in the work of which the slide rule is used exclusively for many purposes; in the computation work of single and double theodolite observations, the computation of mean wind velocities and directions at various altitudes above sea level, in the reduction of the aerological data from kite flights to various levels, etc. Twenty-inch slide rules are used chiefly for such computations. The slide rule is particularly well adapted to this work, for the 20-inch rule yields three figures accurately and the fourth approximately. Four figures represent the maximum accuracy that is readily attainable in meteorological observations, and consequently the 20-inch rule is entirely satisfactory for this work, and it is very expeditious.

In many of these computations the approximate magnitude of the result is already known. This still further expedites the computations, but in the general use of the slide rule, especially when there are several factors involved in the computation, difficulty or delay is often encountered in locating the position of the decimal point in the result.

The usual method of locating the position of the decimal point in a result obtained on the slide rule is by guessing at it, or by a mental approximation. The derivation of the various rules given in slide-rule manuals for this purpose is not immediately obvious, and so these rules must be retained by sheer memory. To my knowledge they are never used. The method outlined below I have found to be the quickest and to involve the least mental effort of any I have tried. The method is very simple to use, but the derivation of it is somewhat tedious.

To multiply two numbers together, their logarithms are added, and the characteristic of the logarithm of the product will equal the sum of the characteristics of the logarithms of the factors unless the sum of the mantissas is greater than 1, in which case 1 will be carried over from the mantissa of the sum to the characteristic. Likewise, in dividing one number by another, the characteristic of the logarithm of the quotient will equal the characteristic of the logarithm of the dividend minus the characteristic of the logarithm of the divisor unless the mantissa corresponding to the divisor is greater than the mantissa corresponding to the dividend, in which case 1 will be borrowed from the characteristic corresponding to the dividend. It is thus evident that the characteristic corresponding to a product is equal either to the sum of the characteristics corresponding to the factors, or to this sum plus 1; and that the characteristic corresponding to a quotient is equal either to the difference of the characteristics corresponding to the factors, or equal to this difference minus 1.

On the slide rule, the ratio to the length of the scale, of the distance of any number on the scale from the left-hand index, is equal to the mantissa of the logarithm of the number. It will be evident from a moment's study of the rule, that when the left-hand index is involved in multiplication, this corresponds to the addition of logarithms in which the sum of the mantissas is less than 1; and that when the left hand index is involved in division, this corresponds to the subtraction of logarithms in which the mantissa of the logarithm of the divisor is less than the mantissa of the logarithm of the dividend. It is important to visualize the lengths of the scale as mantissas of the corresponding numbers. Further study of the rule will show that when the right-hand index is involved in any operation, this indicates, in multiplication, the addition of logarithms in which the sum of the mantissas is greater than 1; or in division, the subtraction of logarithms in which the mantissa corresponding to the divisor is greater than that corresponding to the dividend. See (1) below.

The significance of these statements is that when the left-hand index is involved in an operation, the algebraic sum of the characteristics corresponding to the factors has not been affected—neither increased nor decreased; but when the right-hand index is involved, the algebraic sum of the characteristics corresponding to the factors has been affected, increased by 1 in multiplication or decreased by 1 in division. This statement may be extended as follows:

When the left-hand index only is involved in a series of operations, the characteristic of the logarithm of the result is equal to the algebraic sum of the characteristics of the logarithms of the factors, but whenever the right-hand index is involved in an operation, the characteristic of the logarithm of the result is equal to this algebraic sum plus or minus 1 for each operation in which this index is involved.

This correction (1 for each operation in which the right-hand index is involved) is always applied in the same way as the logarithm of the second factor would be, added in multiplication and subtracted in division. See (2) below.

In performing a series of operations, nothing is regarded except the correction to be applied to the algebraic sum of the characteristics of the logarithms of the factors. These corrections are added cumulatively at each operation, and only the accumulated sum is retained in the mind. We may call this accumulated sum the "accumulated characteristic correction." It is usually very small. We then have the following rule: The characteristic of the logarithm of the result is equal